The Evolution of Electronic Imaging in the Medical Environment

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THE DEVELOPMENT of the electronic radiology department has required the combination of several technologies to solve some of the unique challenges the conversion posed. Radiology Information Systems (RISs) were developed using database technologies to handle the textual information. However, database technology could not adequately handle the size of the images. Hence, a separate entity was created which focused on developing the technology required to manage images—this entity was dubbed Picture Archiving and Communication Systems, or PACS. Finally, a "modality" is a source of these electronic images. The development of these three entities (PACS, RIS, and electronic imaging modalities) were largely departmental efforts to electronically transmit and archive radiologic data. When used in conjunction, these systems allowed improvements in workflow inside the department. RISs could also export text reports to Hospital Information Systems (HIS), and in some cases, images were sent as well (Fig 1). Indeed, it is quite possible that the greatest impact of an electronic radiology department may be outside the radiology department.

However, as the scope of electronic radiology systems enlarge to encompass the enterprise, and as computer technology matures, the RIS-PACS-modality model may be suboptimal. Almost all RIS products and many PACS products are built with the assumption that it is the only one of its kind that exists at a site. Distributed PACS architectures are less prone to this assumption, but as worklist support develops in distributed PACS products, the assumption of exclusivity seems to grow. This architectural assumption of exclusivity is an easy way to implement features helpful in improving workflow.

The assumptions of exclusivity, however, lead to several problems. The first is that it makes product transitions very difficult. For example, if *the* RIS must be upgraded to a newer version, it may be necessary to have downtime, during which the department has substantially reduced productivity (or perhaps nearly none) because the RIS is not available. Taking this one step further, if the upgrade is not backward compatible or a different vendor system is selected, one is faced with 3 options: (1) lose the old data, which for most departments is unthinkable; (2) migrate the data, which in the case of PACS could lead to substantial media costs and which could compromise data accuracy; or (3) maintain the old system and try to integrate it with the new one. If the new RIS (or PACS) assumes it is the *only* RIS (or PACS), option 3 is not possible.

The second problem arises as health care entities begin to merge and there is greater sharing of patients and provider resources. In this case, the boundaries become less clear, and the need for more seamless sharing of data and responsibility increases. In this case, the traditional RIS-PACS-modality model often requires drawing hard boundaries that often are counterproductive. In some cases, the assumption of being the sole archive of information makes integration nearly impossible.

Third, as the integration with institutions that are widely disparate in size occurs, attempting to solve this problem with brute force creates scalability issues. In this case, the very smallest department must "keep up" with the largest.

Another force encouraging change is the increasing strength of institutional bodies such as information services and administration encouraging the shared use of computer resources such as servers and databases. This encourages the centralization of information and the related processes. Whereas before each department might develop its own system, there is now greater interest in identifying common problems and developing common solutions.

While the traditional RIS-PACS-modality model has been of great benefit in the past, it also creates some significant challenges. Therefore, we propose a transaction-based model of the radiology workspace (as opposed to the database model of RIS-PACS-modality) which we believe allows more flexible workflow sharing and scalability to support

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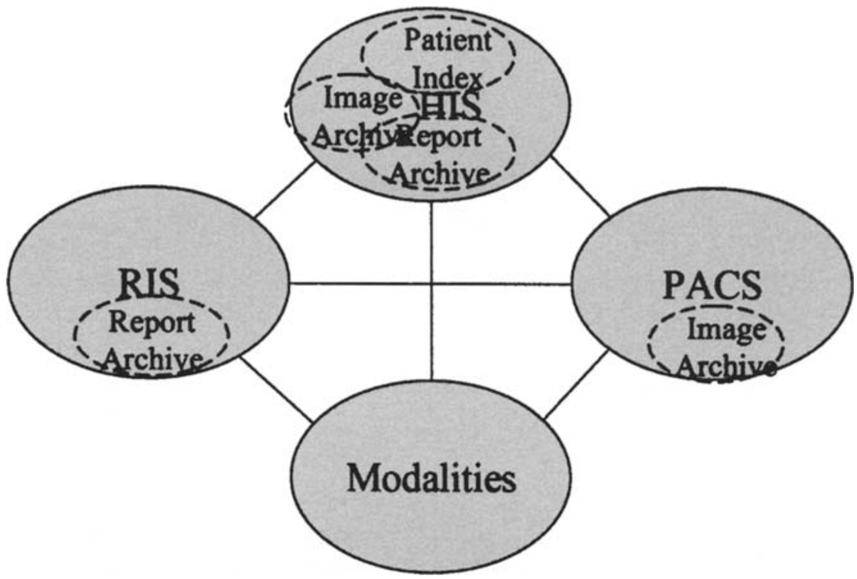

Fig 1. Current RIS-HIS-PACS relationship.

enterprise needs (Fig 2). To simplify the current description, we will assume that the HIS will be responsible for creating orders, scheduling, billing and business administration, a master patient index, and DICOM examination archive(s). One could substitute a comprehensive RIS to provide these functions as well, but we believe the trend will be for the HIS to provide more of these functions,

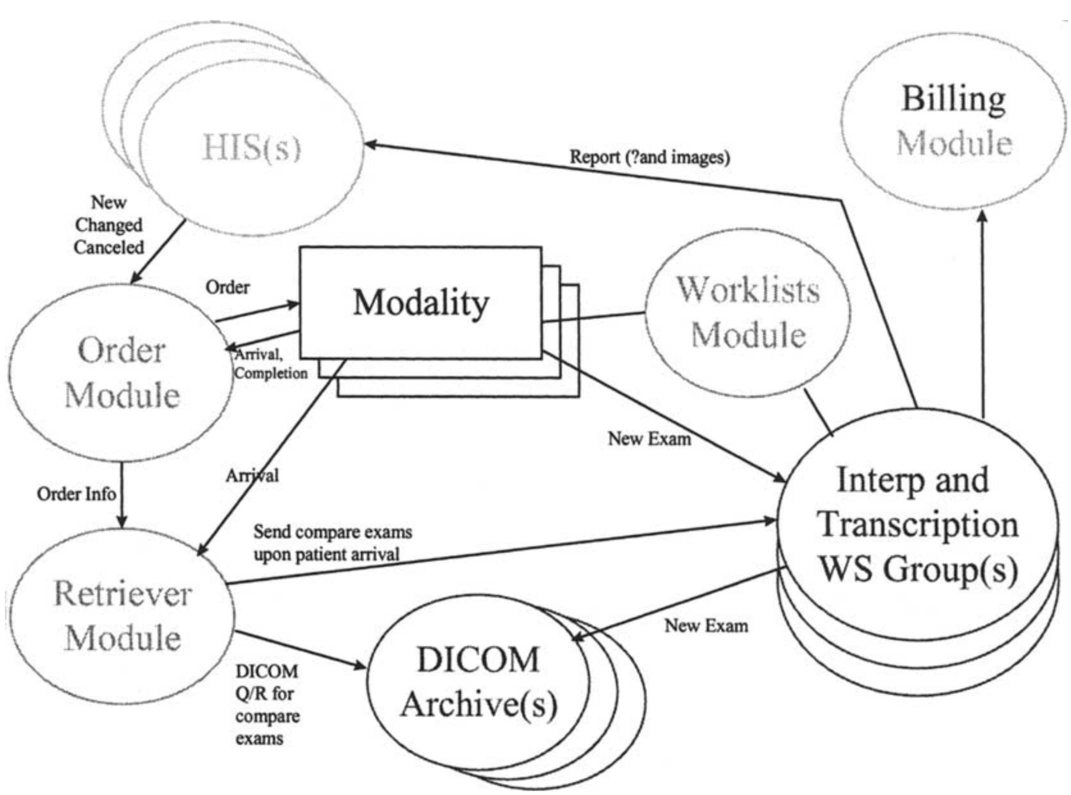

Fig 2. New transaction-based model. The radiology workspace would only have a list of outstanding work to be done, and would delete this information when successfully transmitted to HIS and Image Archive.

because these same functions are needed for nonradiology procedures. We also assume that the DICOM archive(s) have query/retrieve capability and would optimally have the text report (perhaps using structured reporting); the text report could theoretically be retrieved from the HIS, and matched to images using a unique identifier or profiling, but for clarity's sake, we will assume the report comes from the DICOM archive.

There are two key differences between this proposed model and the traditional RIS-PACS architecture. First, only the HIS and the DICOM archives have patient information stored permanently. All information about examinations (from the time it is ordered to the time it is finalized and data sent to be archived) exists in queues which are erased at some point after the last step has occurred, or perhaps when the patient is discharged. There are configurable rules in each module to assist in the development of the queues, and the tasks that occur when an examination is placed on a certain queue.

Consider now, some of the information flow that would transpire in this model. First, an order would be sent from the HIS to an *Order module.* Note that there could be one or more such modules that may or may not correspond with geographic areas. The *Order module* would then "look" at the modality requested, the imaging location requested, and the date. For now, we will assume that the examination is to be done on this campus. If the exam is not to be done "soon" it is placed on a *wait* queue. If it is to be done "soon", it would send a copy of the order to the *Prefetch Module,* and place it on the queue used for responding to modality "Get Worklist" requests. This queue holds the order until two more events occur (unless it is canceled, in which case, it removes the order from its queues, and passes the "cancel" on to the *Prefetch Module*). When the patient "arrives," it directs the *Prefetch module* to send retrieved comparison exams to the interpretation storage device (eg, a PACS, mini-PACS or PACS workstation) based on information in the arrival message. The other event is the completion event (sent from the modality), which it uses to remove the exam from its queues.

The *Prefetch module* retrieves historical examinations for comparison using rules about which and how many previous examinations should be retrieved for each type of newly ordered examination. It will also have a list of one or more query targets (DICOM archives). For those DICOM archives associated with other medical entities, it will use the master patient index facility of the HIS to convert patient IDs to those of the other institution. It will then receive the selected examinations and hold them until the location where the new examination is to be interpreted has been determined, at which time the comparison examinations are transmitted to that location as well.

The third and final component is the *Worklists module.* This module receives a message from the modality when an examination is completed. At that point, it would place the examination on its list of exams ready for Quality Checking (QC). When the QC step is done, the *Worklist module* will move the examination to the workstation or server where the examination is to be interpreted. The retriever module will also be notified of this location. Each interpretation station would then be directed to look to one of these *Worklist* modules for obtaining its worklist. When an examination has been selected for interpretation, the workstation will send a message to the *Worklist module* indicating this status. The exam will be held in the list (but placed lower on the list to avoid having others select it for interpretation) until the interpretation workstation indicates that it has been interpreted. At that point, the exam would be removed from the queue. Depending on the configuration, the order might be passed on to a queue for review and 'finalization' of the report, or simply erased. Nearly all of this *Worklist module* exists in some distributed PACS configurations today.

Once the examination is reported, the report text and exam descriptor is sent to the HIS for clinician viewing and for billing. Images and reports are sent to the DICOM archive. The exam might be held on the workstation for some variable period of time, and then removed. At this point, there is no longer any record of this examination in the radiology workspace—it only exists in the HIS and in the DICOM archive.

Now consider a slightly more complex scenario—one where the patient had a previous CT examination of the chest at an affiliated institution. In this case, when the *Prefetch module* issues its query, it must have access to (and know about) the DICOM archive(s) used by the affiliated institution. This is a rather minor technical challenge. More challenging is to properly identify the patient to the DICOM archive. A Master Patient Index, which assists in the conversion of patient IDs from one institution to that of another, would make this problem quite manageable. If no mechanism exists for uniquely identifying the patient to the other systems, it will be necessary to use multiple fields to try to identify the patient. This is a drawback—without a certain identifier, inefficient DICOM queries must be performed, and the results "profiled" to try to determine which results are true matches. However, this problem is not unique to this design, and is required of any attempt to tie institutions together. Once the exams for the proper patient are identified, those that meet the retrieval criteria are retrieved and stored in the temporary store of the retriever module. When images for the new examination begin to be sent to the interpretation workstation, these comparison images could also be sent.

Finally, consider the case where a physician from one institution (Inst A) orders an examination to be performed at another institution (Inst B), which must be interpreted at a third institution (Inst C). In this case, the *Order module* for Inst A would note that the examination had been requested for a location for which it was not responsible. It would locate the *Order module* which was responsible for that modality, and pass the order on to it. The processing of the order would happen as described above until completion. At this point, the *Worklists module* would place it in the queue for QC at the performing location. When QCed, the *Worklists module* would note that it is after 6PM, and that images of this type must be interpreted at another institution (Inst C). It would pass the order on to the *Worklists module* of that institution. It would also pass the address of the interpretation module to the *Prefetch module* so that it could send any comparison examinations it had retrieved. Once the examination is interpreted, the reporting module will note that the order originated at another institution, and it will pass the results back to that HIS. However, the intermediate institution will be passed billing information about the procedure in order to get credit for the technical portion; the reporting institution will similarly get the professional portion of the reimbursement. Guaranteeing that this is all recorded for the same patient again requires the existence of an enterprise-wide unique identifier (or a process for ID conversion) among all participants.

There are several benefits to this architecture. It allows worksharing within and across sites even if they have disparate information systems. It is scaleable—each site only needs as large a system as is required to handle the orders it is expected to fulfill. There is no contention between RIS and HIS for the 'gold' copy of a report. And because of the loose coupling between the transaction processing units, the HIS, and the DICOM archive, making the transition to new products while maintaining old data becomes much easier. Other imaging departments need only provide the right workspace (for their workflow) with less duplication of expensive resources (like the archive), and greater interoperability.